# MDOT DRAINAGE MANUAL MASTER TABLE OF CONTENTS

## Revised January 2006

Chap	ter 1 - I	ntroduction	
1.1	Introdu	iction/Purpose	1-3
1.2	Overvi	ew	1-3
	1.2.1	Legal Policy and Procedure (Chapter 2)	1-3
	1.2.2	Hydrology (Chapter 3)	1-3
	1.2.3	Natural Channels and Roadside Ditches (Chapter 4)	1-4
	1.2.4	Culverts (Chapter 5)	1-4
	1.2.5	Bridges (Chapter 6)	1-4
	1.2.6	Road Storm Drainage Systems (Chapter 7)	1-4
	1.2.7	Stormwater Storage Facilities (Chapter 8)	1-4
	1.2.8	Stormwater Best Management Practices (BMPs) (Chapter 9)	1-4
	1.2.9	Pump Stations (Chapter 10)	1-4
1.3	Manua	lls, Computer Programs, and Regulations	1-5
1.4	Refere	nces and Hyperlinks	1-5
1.5	Enviro	nmental Protection	1-5
1.6	Update	es	1-5
Chap	ter 2 - L	egal Policy and Procedure	
2.1	Introdu	action/Purpose	2-5
2.2	Definit	ions	2-6
	2.2.1	Types of Watercourses	2-6
	2.2.2	Classification of Waters	2-6
2.3	Role o	f the Designer/Project Manager	2-8
2.4	Order	of Law Supremacy and Related Publications	2-9
2.5	Policy	and Procedures	2-10
	2.5.1	General Procedures	2-10
	2.5.2	Legal Precedent to Discharge Surface Water	2-10
	2.5.3	Types of Right-of-Way Easements or Conveyance for Drainage	2-11
	2.5.4	Drainage Considerations	2-11
	2.5.5	Intracounty and Intercounty Drainage Systems for State	
		Trunkline Stormwater	2-17
	2.5.6	Relocation of Existing Drainage Course	2-18
	2.5.7	Relocation of Field Tile Drains	2-18
	2.5.8	Design Procedures for Unknown Field Tile Location	2-20
2.6	Draina	ge Design Overview	2-21

2.7	General	Design Guidance	2-22
	2.7.1	Location and Flood Hazards	2-22
	2.7.2	Construction and Maintenance	2-23
	2.7.3	Interagency Coordination and Environmental Clearances	2-24
	2.7.4	Intra-agency Coordination and Environmental Permits	2-25
2.8	Federal I		2-27
	2.8.1	Drainage	2-27
	2.8.2	Significant Transportation Laws Related to Highway Drainage	2-28
	2.8.3	Navigable Waters Regulations	2-29
	2.8.4	Federal Agencies	2-29
	2.8.5	Executive Orders	2-31
2.9	State Lav	W	2-33
	2.9.1	Common Law and Statutory Law	2-33
	2.9.2	Basic Concepts	2-33
	2.9.3	Surface Waters	2-34
	2.9.4	Stream Waters	2-34
	2.9.5	Groundwater	2-35
	2.9.6	Statutory Law	2-35
	2.9.7	Eminent Domain	2-35
	2.9.8	Water Rights	2-36
	2.9.9	Drain Code and Agricultural Drainage Laws	2-36
	2.9.10	Environmental Laws and Permits	2-36
	2.9.11	Exemptions to MDEQ Environmental Permits	2-39
2.10	Local La	W	2-43
	2.10.1	Municipal Liability	2-43
	2.10.2	Acts of Others	2-44
	2.10.3	Acts of Developers	2-44
Chap	ter 3 - Hy	drology	
3.1	Introduct	ion/Purpose	3-4
3.2	Definition	ns .	3-5
3.3	Policy ar	nd Design Criteria	3-8
	3.3.1	Data Collection and Evaluation of Runoff Factors	3-8
	3.3.2	Policy of Flood Hazards/Design Frequency	3-8
	3.3.3	Coordination	3-9
	3.3.4	Documentation	3-10
	3.3.5	Flood History	3-10
	3.3.6	Rainfall Data and Flood Frequency	3-10
	3.3.7	Hydrologic Method Selection	3-11
	3.3.8	Hydrologic Analysis Procedure Flow Chart	3-12
	3.3.9	Calibration of Hydrologic Models by MDEQ	3-12
	3.3.10	Rainfall Distribution	3-14

Table	of Content	S	TOC-
3.4	Design	Guidance and Procedure	3-15
	3.4.1	Rational Method	3-15
	3.4.2	Rational Method Procedure	3-21
	3.4.3	Rational Method - Example	3-21
	3.4.4	SCS Rainfall - Runoff Relationship	3-23
	3.4.5	Other Hydrograph Methods	3-24
	3.4.6	Methods Used for Watersheds Regulated by MDEQ	3-25
Chap	pter 4 - N	latural Channels and Roadside Ditches	
4.1	Introdu	ction/Purpose	4-5
4.2	Definition	ons	4-6
4.3	Policy a	and Design Criteria	4-7
	4.3.1	Federal Policy	4-7
	4.3.2	MDOT Policy	4-7
	4.3.3	Stream Channel Design	4-7
	4.3.4	Roadside Ditches	4-7
4.4	Design	Guidance and Procedure	4-8
	4.4.1	Hydraulic Analysis for Stream and Roadside Ditches	4-8
	4.4.2	Example: Calculation of Effect of Tailwater Condition on	
		Channel Water Surface Profile	4-27
	4.4.3	Channel Design Procedure	4-30
	4.4.4	Stream Morphology	4-36
4.5	Mainte	nance	4-37
	4.5.1	Ditch Maintenance	4-37
	4.5.2	Erosion and Vegetation	4-37
	4.5.3	Repairs	4-37
Chap	oter 5 - C	ulverts	
5.1	Introdu	ction/Purpose	5-5
5.2	Definition	ons	5-6
5.3	Policy a	and Design Criteria	5-9
	5.3.1	Introduction	5-9
	5.3.2	Culvert Policy	5-11
	5.3.3	Culvert Environmental Permit Requirements	5-13
	5.3.4	Culvert Design Considerations	5-13
	5.3.5	End Treatment (Inlet or Outlet)	5-17
	5.3.6	Culvert Extensions and Replacements	5-23
	5.3.7	Bedding and Filling Around Pipe Culverts	5-25
	5.3.8	Related Designs	5-25
	5.3.8	Related Designs	5-2

Table	of Contents	s	TOC-
5.4	Design	Guidance and Procedure	5-26
• • •	5.4.1	Approach	5-26
	5.4.2	Inlet Control	5-26
	5.4.3	Outlet Control	5-29
	5.4.4	Outlet Velocity	5-35
	5.4.5	Roadway Overtopping	5-36
	5.4.6	Performance Curves	5-37
	5.4.7	Culvert Design Procedure	5-38
	5.4.8	Nomograph Design and Analysis	5-43
	5.4.9	HY8 Computer Program	5-48
5.5	Mainter	, •	5-60
	5.5.1	Culvert Maintenance and Inspection	5-60
	5.5.2	Cleaning	5-60
	5.5.3	Lining Culverts	5-60
Chap	oter 6 - B	ridges	
6.1	Introdu	ction/Purpose	6-5
6.2	Definition	ons	6-6
6.3	Policy a	and Design Criteria	6-7
	6.3.1	General Policy and Design Criteria	6-7
	6.3.2	MDOT Policy and Design Criteria	6-7
	6.3.3	Coordination, Permits, and Approvals	6-9
	6.3.4	Bridge Deck Drainage	6-9
6.4	Design	Guidance and Procedure	6-10
	6.4.1	Design Procedure Outline	6-10
	6.4.2	Hydraulic Performance of Bridges	6-11
	6.4.3	Methodologies	6-15
	6.4.4	HEC-RAS Modeling	6-16
	6.4.5	Bridge Scour	6-18
	6.4.6	Hydraulic and Scour Analysis Documentation	6-26
	6.4.7	Example Problem - Bridge Hydraulic and Scour Analysis	6-26
	6.4.8	Bridge Deck Drainage	6-58
6.5	Mainter	nance	6-59
	6.5.1	Introduction	6-59
	6.5.2	Inspection	6-59
	6.5.3	Maintenance Problems	6-59
	6.5.4	Maintenance Measures	6-60

Chap	pter 7 - Ro	oad Storm Drainage Systems	
7.1	Introduc	ction/Purpose	7-6
7.2	Definition	ons	7-7
7.3	Policy a	nd Design Criteria	7-10
	7.3.1	Introduction	7-10
	7.3.2	Storm Sewers	7-10
	7.3.3	Bridge Decks	7-11
	7.3.4	Curbs, Inlets, and Flumes	7-11
	7.3.5	Detention Storage	7-11
	7.3.6	Gutter Flow	7-11
	7.3.7	Hydrology	7-12
	7.3.8	Drainage Structures and Manholes	7-12
	7.3.9	Locating Storm Sewers, Manholes, and Inlets	7-12
	7.3.10	Roadside and Median Ditches	7-13
	7.3.11	System Planning	7-13
7.4	Design	Guidance and Procedure	7-14
	7.4.1	Roadways with Enclosed Drainage	7-14
	7.4.2	Depressed Roadways	7-14
	7.4.3	Pavement and Bridge Deck Drainage	7-14
	7.4.4	Drainage Structures	7-25
	7.4.5	Inlet Locations	7-29
	7.4.6	Inlet Spacing	7-30
	7.4.7	Manholes	7-57
	7.4.8	Storm Drain Systems	7-61
	7.4.9	Hydraulic Grade Line	7-68
	7.4.10	Example Problem	7-83
	7.4.11	Sag Culverts (Submerged Culverts, Inverted Siphons)	7-91
	7.4.12	Underdrains	7-91
7.5	Mainten	ance	7-92
	7.5.1	Drainage Structures	7-92
	7.5.2	Storm Drains	7-92
Cha	oter 8 - St	ormwater Storage Facilities	
8.1	Introduc	ction/Purpose	8-5
	8.1.1	Storage Overview and Acceptable Drainage Outlets	8-5
	8.1.2	Computer Programs	8-5
8.2	Definition	ons	8-6
8.3	Policy a	nd Design Criteria	8-8
	8.3.1	Introduction	8-8
	8.3.2	Water Quality Control	8-8
	8.3.3	Water Quantity Control	8-10

Table	of Content	S	TOC-
	8.3.4	Fencing	8-13
	8.3.5	Release Rate and Storage	8-13
	8.3.6	Grading and Depth	8-13
	8.3.7	Structural Controls	8-13
	8.3.8	Location	8-14
	8.3.9	Regulatory Concerns	8-14
8.4	Design	Guidance and Procedures	8-15
	8.4.1	Detention Basins	8-15
	8.4.2	Retention Basins for Regional Use/Watersheds	8-21
	8.4.3	First Flush Basins	8-24
	8.4.4	Infiltration Facilities	8-25
	8.4.5	Erosion/Sediment Traps	8-32
	8.4.6	Outlets	8-32
	8.4.7	Hydrograph Routing Procedure Overview	8-39
	8.4.8	Routing Calculations	8-45
8.5	Mainter	nance	8-51
	8.5.1	Introduction	8-51
	8.5.2	Maintenance Program	8-52
	8.5.3	Inspection Intervals	8-52
	8.5.4	Maintenance Tasks	8-53
	8.5.5	Operation Maintenance	8-53
	8.5.6	Volume Maintenance	8-54
Chap	ter 9 - S	tormwater Best Management Practices (BMPs)	
9.1	Introdu	ction/Purpose	9-3
	9.1.1	Non-Point Source Pollution Overview	9-3
	9.1.2	Soil Erosion and Sedimentation Control	9-4
9.2	Definition	ons	9-6
9.3	Policy a	and Design Criteria	9-7
	9.3.1	Federal Policy	9-7
	9.3.2	AASHTO Policy	9-7
	9.3.3	MDOT Policy	9-7
9.4	Design	Guidance and Procedure	9-9
	9.4.1	BMP Selection Process	9-9
	9.4.2	MDOT-Approved BMPs	9-13
Chap	ter 10 - I	Pump Stations	
10.1	Introdu	ction	10-4
10.2	Definition	ons	10-6

Table	of Contents		TOC-7
10.3	General	I Design Criteria	10-8
	10.3.1	Hydrology and Storage	10-8
	10.3.2	Station Design	10-10
	10.3.3	Outlet Design/Discharge System	10-22
10.4	Mechan	nical System	10-23
	10.4.1	Pump Types	10-23
	10.4.2	Pump Selection	10-25
10.5	Electrical System		10-27
	10.5.1	Requirements	10-27
	10.5.2	Code Compliance	10-28
	10.5.3	Operation	10-28
	10.5.4	Power Supply and Service Connections	10-28
	10.5.5	Materials	10-28
	10.5.6	Installation and Wiring	10-31
	10.5.7	Grounding	10-32
10.6	Retrofitt	ting	10-33
10.7	Mainten	nance	10-34

#### **LIST OF APPENDICES**

Appendix 2-A	Symbols and Acronyms	2-A-1
Appendix 2-B	Federal Policies and Laws	2-B-1
Appendix 2-C	National Flood Insurance Program	2-C-1
Appendix 2-D	Roads and County Drains Guideline	2-D-1
Appendix 2-E	Corps Watercourse Jurisdiction Listing	2-E-1
Appendix 2-F	State Executive Order 1977-4	2-F-1
Appendix 3-A	Symbols and Acronyms	3-A-1
Appendix 3-B	MDOT Rainfall Tables	3-B-1
Appendix 3-C	Computing Flood Discharges for Small Ungaged Watersheds	3-C-1
Appendix 3-D	Wetland Hydrology – The Water Budget	3-D-1
Appendix 4-A	Symbols and Acronyms	4-A-1
Appendix 4-B	MDEQ Cross Section Guidance (Modified for MDOT)	4-B-1
Appendix 4-C	Open Channel Theory	4-C-1
Appendix 5-A	Symbols and Acronyms	5-A-1
Appendix 5-B	Tables of Manning's n, Loss Coefficients, and Worksheets	5-B-1
Appendix 5-C	Culvert Design Charts	5-C-1
Appendix 5-D	Culvert Design Table	5-D-1
Appendix 6-A	Symbols and Acronyms	6-A-1
Appendix 6-B	Summary Hydraulic Analysis Form	6-B-1
Appendix 6-C	MDOT Hydraulic Report Format and	
	Supporting Documents	6-C-1
Appendix 6-D	MDOT Guidelines for Evaluation of Scour and	
	Scour Analysis Worksheets	6-D-1
Appendix 7-A	Gutter and Inlet Capacity Charts	7-A-1
Appendix 8-A	Symbols, Definitions, and Abbreviations	8-A-1
Appendix 9-A	Symbols and Acronyms	9-A-1
Appendix 9-B	Cost List for MDOT-Approved BMPs	9-B-2
Appendix 10-A	Symbols and Acronyms	10-A-
Appendix 10-B	Pump Station Hydraulic Design Example	10-B-

### **LIST OF FIGURES**

Chap	iter 2	
2-1	Sewer Participation Sketch	2-16
Chap	iter 3	
3-1	Representation of Hydrograph, Hyetograph and Rainfall Excess	3-6
Chap	iter 4	
4-1	Cross Section of Reaches, Segments, and Subsections Used in	
	Assigning n Values	4-9
4-2	Switchback Phenomenon	4-14
4-3	Trapezoidal Channel Capacity Chart	4-16
4-4	Trapezoidal Channel Nomograph for Normal Depth	4-17
4-5	Stream Profile	4-19
4-6	Cross Section (Station 4+46)	4-19
4-7	Channel Computation Form	4-21
4-8	Stage Discharge Curve for Cross Section 4+46	4-23
4-9	Profile Convergence Pattern Standard Step Computation	4-25
4-10	Profile Study Limits	4-26
4-11	Example Cross Sections	4-28
4-12	Channel Profile	4-29
Chap	iter 5	
5-1	Culvert Terms	5-6
5-2	Box Culvert Invert Placement	5-16
5-3	Unsubmerged, Transition, and Submerged	5-27
5-4	Unsubmerged Flow	5-28
5-5	Submerged Flow	5-28
5-6	Full Flow Energy and Hydraulic Grade Lines	5-31
5-7	Full Flow in the Culvert	5-33
5-8	Partly Full Flow	5-34
5-9	Partly Full Flow when Tw < d <sub>c</sub>	5-34
5-10	Partly Full Flow when Tw > d <sub>c</sub>	5-35
5-11	Overall Performance Curve	5-38
5-12	Chart 17 and Performance Curve for Design Example	5-45
Chap	iter 6	
6-1	Bridge Hydraulics Definition Sketch	6-13
6-2	Bridge Flow Types	6-14
6-3	Cross-Section Locations in the Vicinity of Bridges	6-17
6-4	Fall Velocity of Sand-Sized Particles	6-20

Table	of Contents	TOC-10
6-5	Adjustment of Abutment Scour Estimate for Skew	6-24
6-6	Plan View of Bridge and River Reach	6-28
6-7	Existing Conditions Water Surface Profile During 1 Percent Chance (100-year) Storm (Printout from HEC-RAS)	6-37
6-8	Proposed Conditions Water Surface Profile During 1 Percent Chance	6-38
6-9	(100-year) Storm (Printout from HEC-RAS)  1 Percent Chance (100-year) Storm Scour	6-47
6-10	0.2 Percent Chance (500-year) Storm Scour	6-48
Chap	iter 7	
7-1	Hydraulic and Energy Grade Line	7-7
7-2	Flow in Triangular Gutter Sections	7-20
7-3	Ratio of Frontal Flow to Total Gutter Flow	7-21
7-4	Flow in Composite Gutter Sections	7-22
7-5	V-Type Gutter	7-24
7-6	Inlet Types	7-27
7-7	Slotted Inlet	7-28
7-8	Velocity in Triangular Gutter Sections	7-33
7-9	Grate Inlet Frontal Flow Interception Efficiency	7-34
7-10	Sketch of Spread	7-35
7-11	Grate Inlet Side Flow Interception Efficiency	7-37
7-12	Grate Inlet Capacity in Sump (Sag) Conditions	7-41
7-13	Curb Opening and Longitudinal Slotted Drain Inlet Length	7 11
711	for Total Interception	7-44 7-45
7-14 7-15	Curb Opening and Slotted Drain Inlet Interception Efficiency	7-45 7-48
	Depressed Curb Opening Inlet Capacity in Sag Locations	_
7-16 7-17	Location of Supplemental and Sag Inlets  Manhole Sizing Example	7-52 7-59
7-17 7-18	Nomograph for Computing Required Size of Circular Storm Sewer	1-59
7-10	for Full Flow, n = 0.013	7-65
7-19	Values of Hydraulic Elements of Circular Section for Various Depths of Flo	
7-20	Deflection Angle	w 7 00 7-72
7-21	Relative Flow Effect	7-73
7-22	Benching Types	7-74
7-23	Use of Energy Losses in Developing a Storm Sewer System	
	Improper and Proper Designs	7-81
7-24	Example Plan and Profile	7-83
7-25	Sewer Profile with Calculated HGL Elevations	7-89
-		

**Chapter 8** 

8-1

8-2 8-3 **Example Weir Structure** 

Detention and First Flush Basin

Methods of Increasing the Length-to-Width Ratio

### MDOT Drainage Manual

8-18

8-19

8-20

Table	of Contents	TOC-11
8-4	Retention Basin	8-23
8-5	Infiltration Basin	8-28
8-6	Infiltration Trench with Leachate Drainage Structure and Perforated Pipe	8-30
8-7	Sharp-Crested Weir (No End Contractions)	8-33
8-8	Sharp-Crested Weir (Two End Contractions)	8-33
8-9	Sharp-Crested Weir and Head	8-33
8-10	Weir Flow Over Sloping Weir	8-35
8-11	Discharge Coefficients for Flow over Roadway Embankments	8-37
8-12	Perforated Pipe with Riser Tube Outlet	8-38
8-13	Example Stage-Storage Curve	8-39
8-14	Example Stage-Discharge Curve	8-40
8-15	Riser Pipe/Outlet Tube Structure	8-42
8-16	Riser Pipe/Outlet Tube Stage-Discharge Curve	8-44
8-17	Stage-Storage Curve	8-48
8-18	Stage-Discharge Curve	8-48
8-19	Plot of Routed Hydrograph	8-50
Chap	ter 9	
9-1	Stormwater BMP Selection Form	9-14
Chap	ter 10	
10-1	Estimating Required Storage	10-9
10-2	Sample Submersible Pump Layout	10-12
10-3	Sample Vertical Pump Layout	10-13
10-4	Sample Dry Pit Station Layout	10-14
10-5	Pumps with Cyclical Running Alternation	10-17

### **LIST OF TABLES**

Chap	iter 2	
2-1	Recurrence Interval Factors	2-15
2-2	Range of Runoff Coefficients for Various Land Surface Types	2-17
Chap	ter 3	
3-1	Runoff Coefficients for Rational Formula	3-20
Chap	ter 4	
4-1	Values of Manning's Roughness Coefficient n (Uniform Flow)	4-12
4-2	Cross Section Data (Station 4+46)	4-18
4-3	Cross Section Data	4-27
4-4	Output Table from HEC-RAS for Profile shown in Figure 4-12	4-30
4-5	Permanent Stabilization Treatments for Various Ditch Grades	4-35
Chap	ter 5	
5-1	Guidelines for Culvert End Treatments within the Clear Zone	5-18
5-2	Equivalent Circular and Box Culvert Sizes	5-24
Chap	ter 6	
6-1	Bed Material Transport Exponent	6-19
6-2	Correction Factor, K₁ for Pier Nose Shape	6-22
6-3	Correction Factor, K <sub>2</sub> for Angle of Attack of Flow	6-22
6-4	Increase in Equilibrium Pier Scour Depths (K <sub>3</sub> ) for Bed Condition	6-22
6-5	Abutment Shape Coefficients	6-24
6-6	Cross-Section Data	6-29
6-7	Existing Profile Output Tables	6-33
6-8	Proposed Profile Output Tables	6-34
6-9	Proposed 1 Percent Chance (100-year) Storm Cross Section Data	6-35
6-10	Proposed 0.2 Percent Chance (500-year) Storm Cross Section Data	6-36
6-11	Standard Drainage Tabulation Form	6-39
Chap	ter 7	
7-1	Manning's n for Gutter or Pavement Types	7-17
7-2	Supplemental Inlet Locations	7-51
7-3	Inlet Spacing Computation Sheet	7-56
7-4	Manhole Maximum Pipe Size	7-59
7-5	Conveyance Factor and Pipe Sizes	7-64
7-6	Minimum Sewer Slopes	7-67
7-7	Frequencies for Coincidental Occurrence	7-69
7-8	Correction Factors for Benching	7-75

Table of Contents		TOC-13
7-9	Storm Sewer Preliminary Layout Worksheet	7-78
7-10	Storm Sewer Hydraulic Grade Line Worksheet	7-82
7-11	Tabulation Sheet for Design of Storm Sewers, Example	7-84
7-12	Hydraulic Grade Line Computation Form, Example	7-90
Chap	ter 8	
8-1	Storage Volume and Outlet Design Criteria Overview	8-11
8-2	Summary of Considerations for a Detention Basin	8-17
8-3	Summary of Considerations for a Retention Basin	8-22
8-4	Summary of Considerations for a First Flush Basin	8-25
8-5	Summary of Considerations for an Infiltration Facility (Basin/Trench)	8-31
8-6	Broad-Crested Weir Coefficient C Values as a Function of Weir Crest	
	Breadth and Head (feet)	8-34
8-7	Riser Pipe/Outlet Tube Stage-Discharge Example	8-44
8-8	Inflow Hydrograph Data	8-47
8-9	Storage Facility Characteristics	8-47
8-10	Routing Procedure Table	8-49
Chap	ter 9	
9-1	List of MDOT-Approved BMPs	9-14